INEL-96/0178

Letter Report

INEL EVALUATION OF THE BOILING WATER REACTOR OWNER'S GROUP NEDC-32160P TOPICAL REPORT "CALIBRATION INTERVAL EXTENSION"

Jeff L. Hansen
Curtis L. Smith

May 29, 1996

Idaho National Engineering Laboratory
Lockheed Idaho Technologies Company
Idaho Falls, Idaho 83415

Prepared for the
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555
Under DOE Idaho Operations Office
Contract No. DE-ACO7-94ID13223
JCN L1695, Task 14, TAC No. M-85776

EXECUTIVE SUMMARY

This Technical Evaluation Report evaluates the General Electric Nuclear Energy Company Topical Report, NEDC-32160P, "Calibration Interval Extension," prepared for the Boiling Water Reactor Owners' Group (BWROG) Calibration Interval Extension Committee. This evaluation was performed by the Idaho National Engineering Laboratory in support of the Nuclear Regulatory Commission. The NEDC-32160P report provides details of an instrument drift study performed for the BWROG Calibration Interval Extension Committee by General Electric Nuclear Energy Company (GE), to form a basis to recommend changes to member utility safety system instrumentation calibration intervals.

The BWROG instrument drift study was performed for a sample of typical instrumentation used in nuclear power plant safety systems. The purpose of the instrument drift study was to provide BWROG utilities with a method of analyzing selected instrument drift field data for the purpose of projecting drift over time. The projected values of instrument drift obtained from the study are to be used to justify extending the member utility Technical Specification calibration intervals as Cost Beneficial Licensing Actions.

The analysis methods were originally developed as part of the GE Instrument Setpoint Methodology program and have been implemented in a computer program for the BWROG Calibration Interval Extension Committee. In the topical report, GE states that "...the drift analysis in this report has been performed for selected instruments, but the methods can be applied for any calibration interval, not to exceed 36 month plus a 25% grace period, and to different types of instruments." The NEDC-32160P drift analysis used the difference in As-Found/As-Left calibration values from various instrument historical field data. This As-Found/As-Left difference data were statistically compared to design error assumptions to verify that the historical drift does not exceed the design error assumptions. The BWROG maintains that the study results justify extending calibration intervals for safety system instrumentation from 18 to 36 months plus a 25% grace period. In addition to the results of the drift data analyses, the BWROG maintains that the proposed calibration interval extension is justified based on the fact that most instrument failures are identified by channel checks, surveillances, operator observation, and other monitoring methods, rather than the performing calibrations. Further, the BWROG justifies calibration interval extensions for Reactor Protection System, Emergency Core Cooling System, and Isolation Actuation System instrumentation based on the results of a previous reliability assessment performed for these instruments using fault tree unreliability modeling.

The results of the Idaho National Engineering Laboratory (INEL) evaluation raise concern with the conclusion by the BWROG that the methods identified in the drift data analysis justify extending calibration intervals. In addition, the INEL evaluation results do not agree that the

statistical analysis results justify the extended calibration intervals. Further, the results of the INEL technical review do not agree with the BWROG assumption that channel check, surveillances, operator observation, and other monitoring methods will identify instrument drift or failure of the most common BWR Technical Specification-related instrumentation identified.

In summary, the BWROG report is inadequate to justify calibrations interval extensions. To have a potentially acceptable report, the INEL reviewers need to see (at a minimum) the following items adequately analyzed and discussed:

- Before any analysis (e.g., statistical, risk assessment) is performed, a list of the specific instruments affected by the calibration interval should be generated and documented. Performing and documenting analyses for instruments that are of no importance to the issue of calibration extensions only obscures the relevant issues.

- After generating this list of affected instruments, it should be used for three purposes. First, concerns relating to instrument channel inoperability and the potential decreased channel redundancy due to calibrations being performed every other refueling outage must be addressed. Second, operational data (e.g., drift data, exposure times, demands, failures) should be collected for these instruments so that statistical analyses will use relevant data. And third, using instrument drift data, where applicable, the overall reliability impact on instruments due to calibration interval extensions must be assessed.

- When addressing instrumentation operability issues, the analysis and documentation should incorporate all potential functional failure impacts, not only drift-related impacts.

- The drift must use an accepted statistical model where all underlying assumptions are investigated for applicability to the data modeling. Also, the analysis should not arbitrarily filter data and should group all applicable data into appropriate groups. Also of concern is the BWROG data analysis treatment of overlapping calibration intervals.

- The reliability analysis should use accepted modeling practices. All impacts to functional failures must be included in the reliability analysis to account for the increased failure probability of components undergoing increased calibration intervals. Issues, such as common-cause failure potentials and operator error, must be included in the analysis.

- Once the reliability analysis is complete, the overall impact on both the core damage frequency and operational risk should be quantified and documented.

- If, after adequate analysis and documentation is presented and the calibration intervals are extended, a strong feedback loop must be put into place to ensure that drift, tolerance, and operability of affected components are not negatively impacted. The data collection and analysis should reflect the original analysis conclusions. However, due to the extended calibration intervals, obtaining an adequate amount of meaningful data would require many years of data collection. Data obtained from the extended calibration interval would not be timely nor provide effective feedback in analyzing the impact from the calibration interval extension. The BWROG must address the methodology for obtaining reasonable and timely feedback.

- Instrumentation vendor documentation must be provided that supports a 45 month time period if the vendor allowable drift values are cited as supporting justification for the extended calibration intervals.

- The BWROG must provide a methodology for establishing calibration intervals for new safety system instrumentation installed in the future.

It should be pointed out that the SMAZ methodology attempts to predict outcomes of extended surveillance intervals (e.g., 45 month intervals) using much shorter interval data (e.g., 18 month data). As with any statistical method, extrapolating a prediction into the future exaggerates any uncertainty present in the model and the data used in the model. This exaggeration of the overall uncertainty must be factored into the decision-making process.

Lastly, the underlying "theme" of the BWROG analysis and report is that (1) drift is the only issue of concern, (2) drift is not a problem for extended intervals, and (3) therefore extending calibration intervals to long time periods (e.g., 45 months) is acceptable. The INEL reviewers strongly oppose this line of reasoning and maintain that instrument drift is not the only item of concern. The issues raised concerning the BWROG data analysis cause the entire drift analysis to be questionable, thereby invalidating the position of "drift is not a problem." And lastly, extending calibration intervals has a varied impact on plant operations and instrumentation operability. This impact can be quantified by several measures including component/system reliability, core damage frequency, and operational risk. The BWROG report does not adequately address any one of the three measures.

CONTENTS

ACRONYMS

ALARA	As Low As Reasonably Achievable
BWROG	Boiling Water Reactor Owners' Group
GE	General Electric Nuclear Electric Company
GL	Generic Letter
INEL	Idaho National Engineering Laboratory
LCO	Limiting Conditions for Operation
LER	Licensee Event Report
NRC	Nuclear Regulatory Commission
O&M	Operation and Maintenance
OISD	Observed In-Service Difference
PRA	Probabilistic Risk Assessment
SMAZ	Second Moment About Zero

1. INTRODUCTION AND REVIEW OBJECTIVES

This report provides an evaluation of the Boiling Water Reactor Owners Group (BWROG) Licensing Topical Report NEDC-32160P, *Calibration Interval Extension*.[1] Topical Report NEDC-32160P provides details of the instrument drift study performed for the BWROG Calibration Interval Extension Committee by the Nuclear Energy Division of General Electric Company (GE), on a sample of the most common instrumentation used in the member utility safety systems. The purpose of the study was to provide member utilities with a method for analyzing historical instrumentation drift data to enable projecting instrument drift over longer periods. The projected drift values obtained from the study are intended to justify the extension of the current Technical Specification required calibration/surveillance intervals.

The drift analysis used a computer program developed by the General Electric Company as part of the GE Setpoint Methodology Program of NEDC 31336, *General Electric Setpoint Methodology*,[2] for quantifying instrument channel uncertainties affecting safety system actuation setpoints. The GE computer program, "GE Instrument Trending Analysis System (GEITAS)", has been implemented into a quality-controlled computer program (as documented in NEDO-11209-04A, Rev. 8, for safety-related software) for the BWROG Calibration Interval Extension Committee for analyzing instrumentation drift. GE maintains that the drift analysis described in the NEDC-32160P report was performed for selected instrumentation, but the methods used can be applied for any instrument, for any period of time not to exceed 36 months plus a 25% grace period.

The BWROG originally performed the instrument drift study to justify extending the current 18 month refueling calibration intervals to 24 months, to conform to the industry trend in extending the refueling cycles to 24-months. Additionally, some utilities plan on extending their current 18 month calibration intervals to every other refueling outage, allowing performance of approximately half of the instrumentation channel calibrations every 18 months (staggered testing), resulting in 36 months plus a 25% Technical Specification grace period allowance, or a maximum of 45 months between each individual calibration.

On April 2, 1991 the NRC submitted Generic Letter 91-04, "Changes in Technical Specification Surveillance Intervals to Accommodate a 24-month Fuel Cycle," to provide guidance to licensees changing to a 24 month fuel cycle.[3] Generic Letter 91-04 identifies a number of issues which must be addressed in order to provide an acceptable basis for increasing calibration intervals to match 24-month refueling cycles for instruments used to perform safety functions. GL 91-04 identifies specific actions that licensees should address for each of these issues in order to justify a proposed increase in calibration intervals to 24 months, + 25%, or 30 months. Topical Report NEDC-32160P considers each of these issues and the required licensing actions identified in GL 91-04 to support a proposed 36 month calibration interval.

The BWROG maintains the proposed extension of calibration interval provides an overall improvement to plant safety and operations, and the proposed changes will result in cost beneficial licensing actions. The report identifies the following as the most significant improvements:

- Reduced potential for false safety system actuations [fewer events requiring licensee event report (LERs)],
- Reduced radiation exposure to plant personnel [as low as reasonably achievable (ALARA)],
- Reduced test cycles on equipment,
- Reduced diversion of plant personnel and resources for unnecessary testing,
- Reduced challenges to safety systems due to lifting leads,
- Reduced opportunity for error,
- Increased safety system availability,
- Fewer limiting condition of operations (LCOs) due to testing, and
- Lower operations and maintenance (O&M) costs.

The BWROG maintains that the instruments included in Topical Report NEDC-32160P study represent the most commonly used safety system instruments among the committee member facilities.

The BWROG further states that performing instrument calibrations have historically not been the primary indicator of instrument failures, except for the special case of Rosemount Transmitter loss of fill-oil. The BWROG maintains that Channel Check Surveillances, operator observation, and other monitoring methods identify the majority of instrument failures in member utility safety systems. The BWROG also maintains, “the majority of instrument `failures’ are allowable value failures (instrument drift), not total failure of the devices to perform their safety function.”

In addition to a general NEDC-32160P report review (e.g., statistical methods, background information, references, and responses to requests for additional information), the INEL reviewed two specific areas concerning the use of Probability Risk Assessment (PRA) methods:

1. For systems or components affected by increased calibration intervals, documented reliability evaluations should specifically account for time-dependent considerations and common-cause mechanisms.

2. Given changes in system or component reliability due to the increased calibration intervals, the resulting impact on core damage frequency and corresponding risk should be evaluated and documented.

The technical evaluation documented in this report focuses on several items, including: (a) the statistical methods used in evaluating the historical instrument drift data, (b) the methods used in comparing the projected drift to the actual drift data, (c) the analysis methods used in assessing component and system reliability, (d) the PRA methods used in evaluating increased risk, and (e) the assertions made justifying the potential cost savings and benefits. In addition, the evaluation included an assessment of stated assumptions concerning alternative instrument system operability verifications, including: channel check surveillance, operator observation, and other instrument performance monitoring methods which would identify failures. Section 2 of this report provides a brief overview of the technical contents of the BWROG topical report. Section 3 presents a detailed evaluation of the topical report, including relevant comments related to technical issues contained in the report. Section 4 presents the overall conclusions of the technical evaluation. Section 5 provides the references used during the evaluation.

2.0 TOPICAL REPORT DESCRIPTION

This section provides a brief overview of the technical contents of the BWROG Topical Report NEDC-32160P. The BWROG Committee on Calibration Interval Extension was formed in April 1991 because many member utilities believed that major safety improvements, including reduced challenges to safety systems, could be achieved by increasing calibration intervals. The BWROG report presents a basis and supporting analyses for extending the Technical Specification-required, 18-month refueling interval calibrations to 36 months.

The technical basis for the proposed calibration interval extension centers on the BWROG position that: (1) most instrument failures, including sensor drift related failures, are not detected by calibration surveillance testing but through Channel Checks, Channel Functional Tests, Logic System Functional Tests, and operator observation, (2) instrument drift can be projected over time using a drift analysis model already developed by the BWROG setpoint methodology described in Topical Report NEDC-31336 (Reference 2), and (3) member utilities can use the BWROG drift projection techniques to fulfill the requirements of NRC Generic Letter 91-04, Enclosure 2 (Reference 3). Section 2.0 of BWROG Topical Report, NEDC-32160P provides a discussion on NRC Generic Letter 91-04 (Reference 3) requirements, followed by a BWROG response to required action as it relates to the proposed 36-month interval. Section 3.0 of the BWROG report discusses safety, operations, and cost benefits associated with extending safety system instrumentation calibration intervals. Section 4.0 describes the methods used to evaluate field data for the purpose of projecting drift over time. Section 5.0 summarizes the results of the BWROG drift analysis for typical instrumentation. Section 6.0 provides conclusions of the instrument drift analysis methods based on the analyses presented in Section 5.0 of the report. Appendices A through F provide supporting data and information relevant to the drift analysis and proposed interval extension.

3. EVALUATION OF TOPICAL REPORT

This section presents the review and evaluation of the NEDC-32160P Licensing Topical Report and BWROG Committee supporting justification. This section is divided into four subsections corresponding to the major review areas. Each subsection discusses pertinent issues relating to the information provided in the topical report and associated justification.

3.1 NRC Generic Letter 91-04

The BWROG topical report provides detailed discussions on the requirements and licensing actions associated with extending calibration intervals according to NRC Generic Letter (GL) 91-04, Enclosure 2, “Guidance for Addressing the Effect of Increased Surveillance Intervals on Instrument Drift and Safety Analysis Assumptions.”

Many aspects of safety system reliability, availability, and performance must be evaluated before extending the interval between safety system instrumentation Technical Specification calibrations. One of the most significant areas that must be addressed when extending calibration surveillance intervals is instrument drift. Time-related instrument drift affects the errors assumed in the calculation of safety system setpoints and may affect the overall safety system analyses results (GE design allowance is based on RSSS of 6 month drift terms). Since there is a possibility that instrument drift may go undetected between calibrations, an evaluation must determine the effects of extending the calibration interval, and its impact on the assumptions of the safety analysis. The scope of the analysis must confirm that the projected instrument errors caused by instrument drift are acceptable for controlling plant parameters to effect safe shutdown with the associated instrumentation.

Due to improvements in nuclear fuel technology, many U.S. nuclear plants are extending their 18-month refueling cycle to 24 months. As a result, these facilities have proposed increasing the interval between refueling outage instrument calibrations to match the new 24-month fuel cycle. The NRC determined that the refueling outage calibration interval for some safety system instrumentation may be extended for this purpose if a thorough analysis verifying that the extended intervals do not invalidate reliability, availability, and performance assumptions made in the plant safety analysis. In response to the proposed extension of safety system instrument calibration intervals from 18 months to 24 months, the NRC implemented certain guidelines to follow in addressing the affects of instrument drift over the extended 24-month interval. These guidelines were issued on April 2, 1991, in NRC GL 91-04, “Changes in Technical Specification Surveillance Intervals to Accommodate a 24-Month Fuel Cycle” and GL 91-04, Enclosure 2, “Guidance for Addressing the Effects of Increased Surveillance Intervals on Instrument Drift and Safety Assumptions.” Enclosure 2 of GL 91-04, identified specific licensing issues and required actions licensees proposing a 24-month Technical Specification surveillance calibration interval must address. The GL 91-04, Enclosure 2, licensing actions were discussed in detail in BWROG Topical Report NEDC 32160P, “Calibration Interval Extension,” as justification for the increasing the calibration intervals to 36 months plus a 25% grace period (a total of 45 months). The BWROG topical report listed each required action identified in the GL for increasing calibration intervals extension to match a 24 month fuel cycle, and provides a response to each action as applied to the proposed 36 month interval, including the 25% grace period. The specific licensee actions identified, and the associated BWROG responses were reviewed and evaluated as follows:

3.1.1 *“Confirm that instrument drift as determined by As-Found and As-Left calibration data from surveillance and maintenance records has not, except on rare occasions, exceeded acceptable limits for a calibration interval.”*

BWROG Response:
“Analysis of the utilities’ surveillance records show that the projected drift values for 45 months have not been exceeded except on rare occasions.”

It should be pointed out that the response refers to projected drift values based upon the GE setpoint methodology. Like any numerical analysis technique, the results are only as good as the underlying analysis model (and associated assumptions) and the data used in the model. Consequently, any concerns with the GE setpoint methodology would cause question with any application of the methodology, such as calibration interval extensions. There are several concerns with the setpoint methodology discussed in detail in this document in Section 3.3.

The BWROG response states that, “surveillance records show that projected drift values for 45 months have not been exceeded except on rare occasions”, however, no calibration data or other supporting documentation was provided to support the statement.

Additionally, for new instrumentation installed in safety systems, BWROG has not provided a documented methodology for establishing calibration intervals. This concern applies to any application of the calibration extension methodology for instruments without a recorded as-found and as-left calibration history.

3.1.2 *“Confirm that the values of drift for each instrument type (make, model, and range) and application have been determined with a high degree of confidence. Provide a summary of the methodology and assumptions used to determine the rate of instrument drift with time based on historical plant data.”*

"Confirm that the magnitude of instrument drift has been determined with a high probability and a high degree of confidence for a bounding calibration interval of 30 months..."

BWROG Response:
"The BWROG drift study is not dependent upon instrument application for its groupings and is performed for 45 months. The drift analysis is performed to confidence and probability levels consistent with licensing safety analysis. The analysis is based on a 95% probability error with a best-estimate confidence level. When significant data points are analyzed (e.g. greater than 30), then the difference between the best-estimate confidence level and the 95% confidence level is insignificant."

As discussed in Section 3.3 of this report, the overall results of the GE setpoint methodology are expressed in terms of a confirmation ratio. This confirmation ratio is not expressed in terms of confidence levels and is, instead, presented as a point estimate value. Further, the differences between a "best-estimate" and 95% confidence level for the data analysis method provided must be documented. The analysis results must express the overall uncertainty as propagated through the methodology. One potential method of estimating the overall uncertainty that is discussed in Section 3.3 is Monte Carlo sampling. Nonetheless, other concerns with the setpoint methodology (see Section 3.3) must be addressed before the results of the methodology are examined.

3.1.3 *"Confirm that a comparison of the projected instrument drift errors has been made with the values of drift used in the setpoint analysis. If this results in revised setpoints to accommodate larger drift errors, provide proposed Technical Specification changes to update trip setpoints. If the drift errors result in a revised safety analysis to support existing setpoints, provide a summary of the updated analysis conclusions to confirm that the safety limits and safety analysis assumptions are not exceeded."*

BWROG Response:
"The results of our drift evaluation show that field drift is well below the vendor allowables. The individual utilities will confirm acceptability of these drift values in their specific submittals."

The BWROG response refers to vendor allowable values for instrument drift. However, the required action is to confirm that a comparison of the projected drift errors has been made with the values of drift used in the setpoint analysis. Comparison of projected drift values to vendor published allowable values does not meet the intent of the required action. Vendor allowable values for instrument drift are always time dependent, and do not include uncertainties specific to the instrument application.[4, 5] The BWROG must provide direction for analyzing instrument drift and performing acceptable setpoint analyses.

In addition, instrument drift allowable values published by vendors are time dependent. The vendor allowable values for a 45 month calibration interval were not included in the topical report. Therefore, the comparison of the projected instrument drift values and vendor allowable values was not possible.

In the drift study, it was not obvious what field drift values were used in the analysis. One data point may represent one of nine as-found readings taken during a nine point calibration procedure. Or, one data point may represent a “zero,” or a full scale “span,” or a “trip actuation,” reading, recorded during a calibration procedure. Also, it is not clear how individual utilities will confirm acceptability of the instrument drift values from the BWROG study for two reasons. First, the study did not specifically state the need for plant-specific analyses and it seems to be left up to the discretion of the utility. Second, in order to confirm acceptability of instrument drift, acceptance criteria should be specified. An acceptance criteria from the study could be induced by the reader as having a confirmation ratio of less than one, but it is unclear whether this value of one should be a mean value, median value, upper-bound of a confidence interval, bounded by a Bayesian probability interval, etc. The BWROG study does not specify an acceptance criteria for the analysis.

The concerns with the setpoint methodology call to question the application of the methodology and the acceptance criteria for the results of the methodology. Specifically, acceptance criteria must be documented and must incorporate decision making given the uncertainty inherent within the methodology. Also, the drift analysis documentation and guidance must be modified to address calibration for instruments of interest. This modification must denote how to apply the setpoint methodology to a variety of instruments and address how the data is to be collected and analyzed (e.g., trip actuation point versus span, multiple calibration points versus a single reading).

3.1.4 *“Confirm that the projected instrument errors caused by drift are acceptable for control of plant parameters to effect safe shutdown with the associated instrumentation.”*

BWROG Response:
“In general, drift associated with signal conditioners, recorders, and indicators is negligible. Therefore, if the drift associated with the transmitter and trip unit is acceptable, there is no impact on the safe shutdown of the plant due to extending the calibration interval. No further actions are required by the utilities if the drift values are acceptable. In addition, analysis has been performed in Appendix F to summarize the impact on plant reliability due to calibration interval extension. This basis of this analysis is the BWROG work performed for the Technical Specification Improvement Committee which has already been approved by the NRC”.

Two items are important concerning the BWROG response.

First, INEL personnel reviewed the instrumentation analyzed in the topical report to verify that the instrumentation was representative of the instrumentation required for safe shutdown of the plant. The instruments evaluated in the topical report were assumed either contact output devices, which have no variable analog or digital outputs, or rack equipment, not the object of the calibration extension concern. The instrumentation in the study included: (1) temperature switches, (2) pressure switches, (3) DP switches, (4) relays, and (5) trip units. All of these instruments are contact output devices. The trip units and relays included in the study are normally rack mounted instruments, monitored on a quarterly basis as part of Channel Functional Tests and Logic System Functional Tests. Instrumentation used to control plant parameters to effect safe shutdown are typically not contact output devices. Operators typically perform safe shutdown using indicated variables, therefore, instrumentation required for safe shutdown are not represented in the drift study.

Second, the reliability analyses performed by the BWROG for the Technical Specification Committee referenced in the additional Appendix F from the responses to RAI #2 does not include details necessary for the calibration interval extension evaluation.[6] In order to determine the applicability of the analysis to the extension of calibration intervals, information on the reliability calculations must be provided. Examples of this information on the analysis include: specific changes to basic event (i.e., component) failure probabilities, modification of common-cause failure probabilities, changes to the model logic structure, probability truncation levels, time-dependent failure considerations, and impacts due to calibration extensions. These items are discussed in more detail in the PRA consideration section, Section 3.2.

3.1.5 *"Confirm that all conditions and assumptions of the setpoint and safety analyses have been checked and are appropriately reflected in the acceptance criteria of plant surveillance procedures for channel checks, channel functional tests, and channel calibrations."*

BWROG Response:
"The safety analyses conditions and assumptions are associated with the setpoint and the response required of the instrument. The response required of the instrument would not be changed due to calibration extension. The setpoint may be changed and the individual utilities will modify their procedures as appropriate when they are implementing the calibration extension."

INEL personnel evaluated the topical report to determine if any assumptions made in plant setpoints and safety analysis may be affected by the extension of channel calibration intervals. Traditionally, the instrument drift uncertainty included in the calculation of safety system setpoints and assumed in safety analyses increase if a surveillance interval is extended. Licensees proposing an extended surveillance interval must provide assurance that the uncertainty does not exceed the assumptions of these analyses. The INEL review and evaluation of the proposed surveillance interval extension included an in-depth evaluation of the BWROG methodology used to project instrument drift over the extended period of time. The methods described in the drift study for projection of instrument drift over a 45 month test interval are questionable. Section 3.3 in this document provides the evaluation of this methodology.

Calibration drift projection is essential in the validation of safety system setpoints and in providing assurance of safety system actuation and indication of process parameters essential to safe plant operation. Although, a proposed extension of calibration intervals must address many other considerations to ensure that the overall plant safety described in the design basis documentation is not compromised. Current nuclear plant instrumentation and control (I&C) system designs are based on the concept of defense-in-depth (i.e. multiple layers of defense against design basis events). Surveillance programs are established with this concept in mind. The layers of defense included in a well established surveillance program include; Channel Checks, Channel Functional Tests, Channel Calibrations, Response Time Testing, Logic System Functional Testing, and well established program monitoring practices. When proposing the extension of a test interval, the overall test program must be evaluated to ensure that the extension of a test interval does not remove a total layer of defense assumed in the plant safety analysis. When extending channel calibration intervals to every other refueling outage on a staggered test basis, other test/monitoring methods must be evaluated to ensure that these methods still provide assurance of instrument health and performance through an 18-month fuel cycle, a plant shutdown, followed by another 18-month fuel cycle and a possible 25% surveillance allowance.

Typical I&C safety system designs and established surveillance testing programs were evaluated to ensure that adequate defense-in-depth measures justify the proposed interval extension. The evaluation focused on the sample instrumentation provided in the drift study, the BWR 6 Technical Specification markup provided as Attachment 2 of the BWROG letter to Jared S. Wermeil, dated November 20, 1995,[7] and the IEEE Std 338, Criteria for Periodic Testing of Class IE Power and Protection Systems for Nuclear Power Plants.[8]

The instrumentation calibration process required by Plant Technical Specifications consisting of periodic Channel Checks, Channel Functional Tests, Logic System Functional Tests, and Channel Calibrations are performed at various intervals, with each individual test providing overlap to ensure the total instrument channel is functioning properly and is accurate. Typical safety system instrumentation channels can be separated into three major groups; (1) process sensor, (2) signal conditioning (instrument racks), and (3) actuation trip logic. Each surveillance test is designed to test these instrument groups when the group is accessible, without introducing unnecessary challenges to safety systems. The instrument groups which are accessible during plant operation are included in functional test surveillances on a monthly or quarterly test interval. The process sensor normally inaccessible during plant operation is calibrated at refueling intervals. Technical Specification required Channel Checks consist of a comparison of instrument channel readings on panel displays by operations personnel each operating shift. Channel Checks indicate obvious disparity between redundant instrument channels monitoring a common parameter. When a disparity between redundant channels is indicated, corrective measures are taken to correct the disparity. Additionally, instrument channel monitoring methods not required by Plant Technical Specifications are implemented in many nuclear power plants to evaluate instrument channel performance, including on-line operational trending of channel output and calibration data trending. A more detailed description of each of the above surveillance tests and monitoring methods is provided below:

- A Channel Check is a qualitative assessment of the operational behavior of a safety system instrument channel. The output of a field sensor is compared against the output indication of independent and redundant instrument channels monitoring the same parameter. Channel checks are normally performed once per operating shift on most safety system instrument channels in a nuclear power plant. The channel check provides a general indication of instrument channel health and proper functioning.

- A Channel Functional Test is performed on the testable section (during plant operation) of an instrument channel by injecting a simulated process signal into the instrument loop ahead of the signal conditioning equipment and trip logic, as close as practicable to the field sensor. The purpose of the functional test is to verify the operability of the instrument channel except the process sensor, including alarms, trip functions, displays, and interlocks. The channel functional test does not evaluate the operation of the process sensor. The channel functional test is normally performed on a monthly or quarterly surveillance interval.

- A Logic System Functional Test is a test of all required logic components (i.e., all required relays and contacts, trip units, solid state logic elements, etc.) of a logic circuit during plant shutdown. The test is performed by injecting a test signal as close to the sensor as practicable and monitoring the logic system performance up to, but not including the actuated device, to verify operability. The logic system functional test, normally performed on a 18 month refueling basis, does not evaluate the operation of the process sensor.

- A Channel Calibration encompasses the entire instrument loop, from sensor through end devices (e.g. indicator, trip logic, etc.). The process sensor is input with a simulated or actual process variable monitored with test equipment. The sensed input is converted to an electrical signal and transmitted to the signal conditioning equipment (instrument racks), where the signal is converted to a standardized format for use in driving trip logic, displays, and other end devices. The channel calibration includes the adjustment, as necessary, of the channel component outputs such that they respond within a required range and accuracy to known values of the input variable monitored by the channel.

- On-line Operational Trending is utilized in nuclear plants to monitor the performance of safety system instrumentation channels. On-line operational trending is performed by recording the instrument channel current loop values for redundant and independent instrument channels monitoring a common parameter. In some nuclear power plants, on-line operational trending is available through the use of plant computer systems, while in other plants recording devices continuously record instrument channel current loop values. This on-line monitoring method allows a visual comparison of redundant instrument channels monitoring the same parameter over time.

- Calibration Data Trending, another method of monitoring instrument performance uses as-found instrument data recorded during periodic calibrations to generate plots which indicate various calibration errors over time. This measure of instrument performance is only useful for instruments from which considerable calibration data is recorded over long periods of time.

From the descriptions of these four types of periodic instrument surveillance tests, it can be determined that *only Channel Calibrations and Channel Checks are useful in determining process sensor availability and performance*. Channel Functional Tests and Logic System Function Tests are only valid for rack equipment downstream of a process sensor. On-line operational trending and calibration data trending are useful in determining process sensor availability and performance, but are limited by system designs and long test intervals.

The process instrument group (normally mounted, or closely adjacent to the process), are considered to be the most significant drift contributor of all instruments in an instrument channel because of their design and service environment. These instruments are inaccessible during plant operation, therefore calibrations are only performed during periods of plant shutdown. Due to the inaccessibility of process sensor instrumentation during plant operation, their contribution to instrument channel drift, and the extended periods of time between calibrations, the focus of a proposed calibration interval extension is the process sensor instrumentation.

From the information included in the BWROG Topical Report and supporting BWROG justification, it is determined that the process sensor instrument types most common to BWROG member utility I&C designs, do not allow Channel Checks, or on-line operational trending to be performed. For channel checks, and on-line operational trending to be performed, an instrument channel must generate a variable electrical signal proportional to the process input parameter to be compared with redundant channels. The process sensor instruments identified in the BWROG topical report as the most commonly used sensors in member nuclear plant safety systems are contact output devices which do not produce a variable output signal to be compared to redundant instrument channel outputs by operations personnel or through operational trending programs.

Twenty-two instruments were included in the GE drift study. Of the 22 instruments, only 13 instruments are considered process sensor instruments, the other nine do not belong in the study because they are not process sensor type instruments. Twelve of these 13 process instruments are contact output devices which do not provide an output electrical signal proportional to the process input parameter capable of being monitored by Channel Checks or other on-line monitoring methods (i.e. operational trending). One process sensor instrument is included in the study which may provide a variable electrical output signal; a GE Radiation Monitor, model 129B2802G11. The remaining nine instruments are instrument rack instruments, tested on a monthly or quarterly interval as part of a Channel Functional Test or a Logic System Functional Test (LSFT), therefore, not representative of the instruments of concern in the proposed interval extension.

The instruments included in the BWROG drift study, which were identified as the most commonly used in safety systems among the committee members and for which data was analyzed were:

Riley Temperature Switch, model 86A
Riley Temperature Switch, model 86A
Riley Temperature Switch, model 86
Barksdale Pressure Switch, model D2
Barksdale Pressure Switch, model TC
Mercoid DP Switch, model DAW7443RG24E
Gould Brown Relay, ITE 59N
Agastat Relay Switch, model 701
GE Trip Unit, model 184C5988
Rosemount Trip Unit, model 510DU23
GE Radiation Monitor, model 129B2802G11
Riley Temperature Switch, model 86Y
Riley Temperature Switch, model 86P
Barksdale Pressure Switch, model P1H
Barksdale Pressure Switch, model B
Mercoid DP Switch, model D7400
Moduflash Switch, model 652
GE Model 565, Square Root Device
GE Time Delay Relay, model CR2820
Rosemount Trip Unit, model 510DU22
Rosemount Trip Unit, model 510DU24
Rosemount Trip Unit, model 710DU

The instrument types included in the drift study were reviewed to determine if they were a representative sample of process instrumentation of concern in the extension of calibration intervals. From the instrument types included in the study, only 13 were considered process sensor instruments. The 13 process sensor instruments included in the study include:

5 Riley temperature switches,
4 Barksdale pressure switches,
2 Mercoid switches,
1 Moduflash Switch, and
1 GE radiation monitor.

The 9 remaining instruments are instruments included in monthly or quarterly Channel or Logic System Functional Tests, and are housed in environmentally controlled instrument racks or relay cabinets. These 9 instruments include:

1 Gould Brown relay,
1 Agastat relay switch,
1 GE square root device,
1 GE time delay relay,
1 GE trip unit, and
4 Rosemount trip units.

Channel Checks are normally performed every 12 hours during plant operation and, as described in the definition, are a comparison of readings from independent instrument channels monitoring the same process parameter. In order to compare the readings (indicative of drift) from independent instrument channels, the process sensor must be capable of transmitting an electrical output signal proportional to the change in the process input to some indicating device, for comparison. All of the process instruments except the radiation monitor included in the study were assumed to be contact output devices which do not transmit output signals proportional to input process variables. Therefore, all but one of the process sensor instruments included in the study are incapable of providing a performance comparison indicative of instrument drift during a Channel Check Surveillance or on-line monitoring techniques.

The relay devices and trip units included in the drift study are also excluded from Channel Check Surveillance and on-line monitoring techniques because they also have no proportional output signals which allow comparison indicative of instrument availability and performance.

Section 1.0, "Introduction," of the topical report states the "Instrument calibrations have not been the primary method of detecting instrument failures except for the Rosemount transmitter loss of oil (zero and span changes are indicative of future transmitter problems). Utility commitments with the NRC regarding Rosemount transmitters are not changed by this report. Failures are usually detected by operator observations or channel checks, but can also be detected when performing channel or logic system functional tests. The majority of instrument "failures" are allowable value failures (instrument drift), not total failures of the devices to perform their safety function." These instrument allowable value failures render the instrument channel inoperable, placing the plant in a Technical Specification Limiting Condition For Operation (LCO) as determined by the plant safety analysis. The only method of identifying allowable value failures (instrument drift outside acceptance criteria values) is through performance of a Channel Calibration. Therefore, when calibration intervals are extended, these allowable value failures may go undetected for the extended interval period.

Section 2.2, "Purpose of Instrument Calibration," of the topical report states "The purpose of instrument calibrations is to optimize the instrument performance and to correct for any instrument drift. Instrument failures are usually found during Channel Checks, and by operator observation such as alarms or indication differences".

There are several credible failure modes associated with process instrumentation.[9] Some of these failures are detectable and some are not detectable during steady-state and/or transient plant operations. Considering the type of instrumentation commonly installed in BWROG committee member safety systems, most detectable failures during steady-state and/or transient plant operations are gross failures resulting in a total loss of instrument operability (contact output devices). In current safety system designs most of these failures result in a conservative (safe) state. Other failures associated with these safety system instruments can be undetectable during steady-state and/or transient plant operations. These undetectable failures include calibration zero and span shift, non-linearity, hysteresis, and setpoint drift. During normal operation, these undetectable failures may not be recognized, resulting in a safety function failure on demand (e.g. pressure switch hysteresis effecting a safety trip setpoint). The BWROG contact output instrumentation is especially prone to failure upon demand, because the failure modes associated with this instrumentation are normally not detectable during steady-state and/or transient operation. (monitoring of sensor output is not possible)

Most process sensor instrumentation failures are detectable during the performance of Channel Calibration surveillance testing. The only known failures not detectable during a Channel Calibration are response time related failures.[10] Failures such as zero and span shift, non-linearity, hysteresis, and setpoint drift are all detectable during a Channel Calibration.

In conclusion, a number of areas are identified in the evaluation which require evaluation by BWROG to determine the affect on assumptions made in plant Safety Analyses and GE setpoint study. Even though the topical report stated that the primary means for identifying failures in instrumentation is through operator observation, Channel Checks, and other monitoring methods, it is apparent that these methods of detecting instrument failure are not valid for the instrumentation most commonly used in the committee member safety systems and included in the drift study. Therefore, the process sensor instrumentation most commonly installed in BWROG safety systems study would be required to maintain calibration settings within acceptable limits for up to 45 months, with no means of failure detection. Also, the relay devices and trip units included in the drift study are rack mounted instruments located in a mild environment which are tested on a monthly or quarterly interval as part of a Channel Functional Test or a Logic System Functional Test, therefore, not representative of the instruments of concern in the proposed interval extension.

3.1.6 *"Provide a summary description of the program for monitoring and assessing the effects of increased calibration surveillance intervals on instrument drift and its effect on safety."*

BWROG Response:

"Existing utility programs will continue to monitor the results of the instrument surveillances. These programs are adequate and will continue to be utilized to assess instrument performance and its effect on safety."

Several methods can be utilized by licensees to monitor instruments for degraded performance over extended calibration intervals. These monitoring techniques are dependent upon instrument system designs. For example, some plant I&C systems use computer-based digital technology capable of on-line operational trending of instrument performance by sampling instrument loop current over given periods of time (for instruments which have proportional input to output signals). The computer-based digital systems now being retrofit into nuclear plants are especially adapted to monitoring and trending instrument performance. Instrument performance can also be trended over time by plotting instrument calibration data. These are examples of methods licensees may utilize in assessing the effects of increased calibration intervals which must be included in the proposal. Past analyses have shown that ". . . about every 18 to 24 months is generally adequate for the management of normal aging of the transmitters provided that all safety-related transmitters are included in the tests."[11] The topical report does not discuss methods for monitoring the effects of the proposed increase in calibration intervals, and the response provided by the BWROG are not adequate to perform an evaluation of this GL licensing action.

3.2 Probabilistic Risk Assessment Considerations

To help summarize the probabilistic risk assessment (PRA) points concerning the INEL comments on the BWROG topical report NEDC-32160P, several prerequisite assumptions are presented. These assumptions are delineated in order to provide a starting point for discussion by stating a set of analysis assumptions up-front. In performing a risk-based analysis for extending a calibration interval, the following assumptions apply to the analysis:

1. If calibration intervals are extended for various components, it is possible to have an increase in the occurrences (or the probability) of component functional failures. An increase in the occurrence of component functional failures equates to a decrease in the component's reliability.

   ⇨ The ***reliability*** can be thought of as the probability that the component operates as needed over some period of time (called the mission time) given a specified operating condition.

2. If components with increased calibration intervals become less reliable, the reliability of the *system(s)* containing the components decreases.

3. If systems containing components with increased calibration intervals become less reliable, the reliability of the *plant* containing the systems decreases.

4. A decrease in the reliability of the plant results in an increase in the risk of operating the plant over some period of time.

   ⇨ The ***risk*** can be thought of as the probability of experiencing an undesired event multiplied by the consequences of the undesired event.

5. While increasing calibration intervals could decrease the reliability of the plant, other positive benefits to plant operation over some period of time may be realized.

   ⇨ The ***benefit*** can be thought of as the probability of experiencing a desirable event multiplied by the consequences of the of the desired event.

With the assumptions established above, one can go back to any of the items discussed to estimate their contribution to the issue at hand. The following items discuss each of the above assumptions in order of occurrence. The items represent the concerns identified by the INEL that are not adequately addressed by the BWROG report and subsequent response submittals.

3.2.1 Items 1 and 2 — Component and System Reliability Decreases. This section discusses the points related to a decrease in component and/or system reliability. The points discussed in this section are grouped into four categories, summarized as:

1. The reliability analysis alluded to in Appendix F (Reference 6) of RAI #2 needs to be documented and provided for review.

2. Potential impacts to common-cause failures needs to be addressed.

3. Questions of time-dependent reliability modeling needs to be addressed.

4. Data collection and analysis concerns needs to be addressed.

INEL identified concerns for each of the points listed above. The discussion of these concerns reference various documents which form the basis of the technical analysis submitted by the BWROG. These documents include the NEDC-32160P report (Reference 1), questions concerning the NEDC-32160P report,[12] *Responses to the Request for Additional Information #1* (RAI #1),[13] and the *Responses to the Request for Additional Information #2* (RAI #2) (Reference 6). The two Responses to the Request for Additional Information contained attachments as part of the document, including RAI #2 which contained a summary of unreliability analysis and is referred to as Appendix F. The concerns for the four reliability-decrease points are as follows:

1. Reliability analysis alluded to in Appendix F of NEDC-32160P needs to be documented and provided for review

In RAI #2, Question 2.1, it was stated by the INEL that "Changing test or calibration frequencies and durations can cause unexpected changes in overall system reliability. Without a detailed calculation, the actual change in system availability [which can be expected as a result of the change] is unknown. Perform an analysis using time dependent availability and determine the change in system availability." GE provided responses to RAI #2 and included a proposed attachment to NEDC-32160P, labeled "Appendix F," to address this concern.

Appendix F states that the safety system reliability (actually, the failure frequency was calculated) decrease falls into the category of "small" for systems such as the reactor protection system (RPS), emergency core cooling system (ECCS), and isolation actuation. Since details of these analyses are not provided in the documentation, it is not possible to determine what was actually analyzed. Also, modeling assumptions are not provided. Until information is provided for these reliability calculations, it is not possible to judge the analyses results as being either adequate or inadequate. Instead, the INEL has presented items of consideration which should be accounted for when performing the reliability analyses. If details of the BWROG reliability analysis are provided, these items of consideration would form the basis of an evaluation on the analysis.

As a consideration in evaluating the reliability of process instruments that have calibration intervals extended over long periods of time (e.g., two or three years), it may turn out that drift is a minor consideration to overall equipment reliability. The act of recalibration will help ensure equipment operability. This equipment operability may be impacted by degradations other than drift. Examples of these potential degradations include: latent test/repair errors, physical damage due to plant shutdown or at power operations, design defects, dust/corrosion, etc. Functional failures caused by one of the degradations could result in a functionally inoperable component that resides undetected in the plant over a long period of time. Time-dependent reliability analysis have been performed for NRC methodology development and regulatory relaxation as part of other technical analyses.[14,15] These reports and others show that, as test intervals are extended past an optimal point, the corresponding component unreliability increases exponentially. The reliability analysis must be performed to determine the time-dependence and must be documented to reflect this analysis.

2. Potential impacts to common-cause failures needs to be addressed

As part of any reliability analysis, the potential impact on common-cause failures must be evaluated. Common-cause failures generally dominate the potential for failures in reliable safety systems composed of multiple redundant trains. By increasing calibration intervals to extended periods of time for multiple trains, the potential for failures in multiple process components may be increased. This potential impact is not discussed in the NEDC-32160P report.

It was pointed out by the BWROG that a previous GE analysis for a different issue found that common cause failure of the system was a dominant contributor to system failure. The BWROG report does not address the potential impact of common cause failures. Reports discussing common-cause failure modeling generally list the types of common-cause impacts that could be realized. These impacts have coupling mechanisms which include: hardware configuration quality, maintenance/test schedule, test procedures, and testing personnel.[16]

3. Questions of time-dependent reliability modeling needs to be addressed

Another issue related to the reliability analysis is the assumption of time-independence that is normally assumed for a PRA. The reliability models (and consequently failure probabilities) in a traditional PRA assume the component failure rate is constant over the entire mission time. For the process components that fall under the umbrella of the calibration extension, it would have to be demonstrated that the failure rate is indeed time-independent. If the time-independence is not demonstrated, the reliability calculations would need modification to account for the time-dependency. These types of time-dependent calculations have been performed for NRC methodology development (references 14 and 15) and regulatory relaxations.[17]

Appendix F states (page 2, Methodology section) “...for these cases [trip units] the ability to detect excessive drift and functional failures is not dependent on the calibration interval extension and no further evaluation is required.” The ability to *detect* excessive drift or functional failures for trip units at-power is not questioned, however, the analysis of Appendix F is based on trip unit evaluations and data. Trip units are calibrated on a monthly or quarterly test basis, and therefore, are not of concern in extending the Channel Calibration interval.

Appendix F states (page 2, Introduction) “The guidelines provide each utility with a mechanism for assuring that the reliability and availability between calibrations are not degraded when the intervals are extended.” This sentence implies that some method will be provided to the utility that will prevent a change in reliability and availability when calibration intervals are extended. It is not clear that Appendix F is something a utility would *have* to perform (on a plant-specific basis) before extending calibration intervals. If NEDC-32160P is accepted as is, with Appendix F as an attachment, the INEL suggests that a utility must perform component and system reliability evaluations before implementing extended calibration intervals. Consequently, guidance needs to be provided to determine the scope and mechanism of further analysis as part of a calibration extension request.

4. Data collection and analysis concerns needs to be addressed

Several different data collection and analysis concerns have been identified by INEL. Since these concerns are not adequately addressed by the BWROG responses and the discussion text is somewhat lengthy, these concerns are divided into its own subsection. Section 3.3 addresses the INEL data collection and analysis concerns.

3.2.2 Item 3 — Plant Reliability Decrease. This section discusses the points related to a decrease in plant reliability. A decrease in plant reliability will increase the plant’s core damage frequency. The BWROG analysis did not document any analyses made quantifying the potential impact to core damage frequency arising from a calibration interval extension. In order to perform this quantification, the analysis would first have to address component and system reliability impact. Consequently, the concern of plant reliability decrease is related to the items noted in Section 3.2.1. Once the component and system reliability impacts are quantified, the PRA model could be used to estimate the overall change in core damage frequency. This change in core damage frequency could be contrasted or compared to other core damage measures such as the NRC’s safety goal, the plant’s base-line core damage frequency, or other core damage levels from hypothetical plant events. Of course, for this evaluation, the parameter uncertainty should be evaluated along with investigations of model uncertainty.

3.2.3 Item 4 — Increase in Operational Risk. If the plant core damage frequency increases due to increased calibration intervals, the operational risk will also increase. The BWROG analysis did not document any analyses made quantifying the potential impacts to operational risk. The increase in operational risk could be contrasted or compared to other risk decision criteria. For example, the NRC's safety goals or the plant's base-line risk level could be used as part of a decision criteria. A detailed, plant-specific Level 3 PRA is not needed to evaluate operational risk. Instead, simple generic-based consequence analysis like those performed for Generic Safety Issue Resolution could be used.[18]

3.2.4 Item 5 — Increase in Operational Benefit. Although the BWROG report lists various potential benefits that may be derived from increasing calibration intervals, the presentation in the report is one-sided. In RAI 2, Question 2.2, the INEL asked for both benefits and drawbacks of interval extensions. The response to the question did not address potential drawbacks. Consequently, the INEL reviewed the benefits pointed out by the BWROG report, but for each of the benefit areas, potential drawbacks were generated by the INEL and are presented in Section 3.4 of this report.

3.3 Data Collection/Analysis Points

This section discusses the points related to data collection and analysis. The concerns identified by INEL for the BWROG report and question responses fall into four categories. These concerns are:

1. Analyzing plant specific data versus generically grouped data was not effectively discussed.

2. The data analysis program used by the BWROG appears to miss appropriate data intervals during the data analysis.

3. Several assumptions are made for the SMAZ calculation that are not documented nor are they evaluated for their potential impact on plant operation. Some of these assumptions on SMAZ include:

   - The instrument drift is random.
   - No correlations exists from one instrument reading to another for the terms in the equation.
   - The variance of terms in the equation are constant.
   - Analysis data represents a single point.

4. Overall uncertainty in the analysis results are not presented nor discussed.

Discussion for the four data collection and analysis points are provided below.

1. Analyzing plant specific data versus generically grouped data was not effectively discussed

The RAI #2, Question 1.1, presented the need for plant specific data analysis to verify that increased calibration intervals will not degrade component reliability or plant safety. The response to the question stated "Plant specific drift data should not be required...A set of guidelines will be included in NEDC 32160P as a new Appendix F to reflect the need for further evaluation as part of each plant's submittal." As part of the licensing submittal, the BWROG performed "bounding analyses" for select systems as described in the new Appendix F. This bounding analysis was evidently performed using the least reliable system configuration with data collected from grouping plant surveillance data. The INEL issue addressing the need for plant specific data answers the question "What is the risk/safety level increase from extending calibration intervals for a particular plant that has higher component failure rates than the rates from grouped data?" One available method of answering this question is to perform plant specific analysis using plant specific data. Thus, there is a need for plant specific data analysis in order to address the risk of calibration extensions at a particular plant. Additionally, modern statistical techniques such as analysis of variance and empirical Bayes could be used to identify whether grouped data should be pooled or the existence of "outlier" plants.

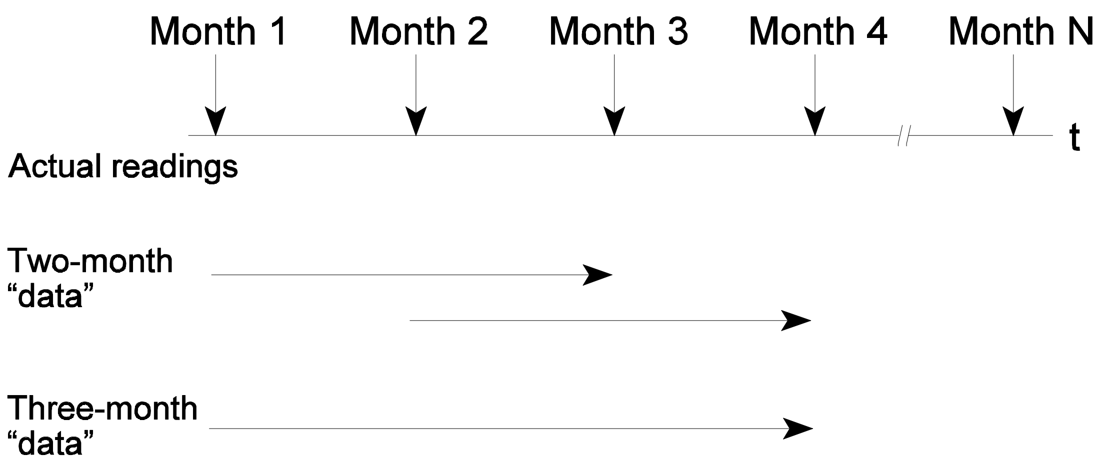
2. The data analysis program used by the BWROG appears to miss appropriate data intervals during the data analysis

Question 4.1, RAI #2 pointed out that the BWROG data analysis program incorrectly groups intervals. The BWROG disagreed and responded to the question. The final sentence in the response to the question stated "The program therefore is considered to appropriately categorize the data." But, if we use the BWROG definition (as stated in their response) of a three month interval (63 days to 116 days), the BWROG data analysis program *is not* appropriately categorizing the data. To demonstrate this problem, a subset of the data presented in the October 1993 meeting was analyzed. This analysis is documented in Appendix A of this report.

Comparing the BWROG program-generated intervals with a set of correct intervals, it was evident that program did not generate nor use several of the three month intervals. The BWROG program missed the majority of valid intervals in this subset of data. Therefore, we conclude that the program ***is not*** correctly grouping and analyzing the surveillance data. The overall impact of the incorrect data grouping is unknown. The impact is expected to be significant for smaller intervals and then could decrease for larger intervals (this impact assumes that the analysis methodology and analyzed data are correct to begin with).

Additionally, the BWROG program output screens data based upon a 3-sigma region. Discarding points outside a 3-sigma region appears to discard appropriate data. The response to question 3, RAI #2, states "...there is an insignificant difference between the confirmation ratios for the two cases [that were examined]...It should be noted that the V&V version of the program does not have the capability to remove the 3 standard deviation outlier criteria." This statement implies that the data analysis is justified in removing these data points and, possibly, this feature will be added to the V&V version. The INEL concludes that the data analysis program should not discard data based upon a 3-sigma region since otherwise appropriate data may be discarded. One exception to this conclusion would be for the case where an instrument was clearly inoperable, and consequently, the data reading for the instrument is not valid (which was the original intent of discarding 3-sigma data).

And lastly, an important concern with the overall BWROG data analysis methodology is that short time interval data (e.g., one , three, or 18-month intervals) are used to come up with pseudo-time intervals of one to 48 months. For example, if data for four one-month time intervals were available, the BWROG data analysis program would generate three one-month data points (a data point is the difference between two instrument readings), two two-month data points (first month to third month and second month to fourth month), and one three-month data point (first month to fourth month). The figure below illustrates this data analysis concept. What is disturbing about this analysis approach is that two and three month data really do not exist. During the time from the first month to the fourth month, the instrument could have been adjusted, recalibrated, cleaned, lubricated, jolted, etc. Any of these impacts to the instrument could alter, possibly subtly, the operation of the instrument over time. Consequently, the differences in data readings from month one to month four are not the same for a component setting untouched for four months compared to a component "impacted" three times during the four months. The fact the data encompasses overlapping time intervals will complicate the



analysis. This complication has not been evaluated by the BWROG. Since the overlapping time interval data causes one set of interval "data" to be dependent on another set (i.e., a single set of data is used to synthesize the spectrum of data from one to 48 months), it is suspected that the overall data analysis results are flawed.

3. *Several assumptions are made for the SMAZ calculation that are not documented nor are they evaluated for their potential impact on plant operation.*

The SMAZ calculations are used as a basis which, according to the NEDC-32160P report, "indicates that the instrument error observed are acceptable..." As such, the evaluation and utilization of the SMAZ calculations have potential impacts on calibration intervals and the corresponding instrument reliability. Thus, the assumptions built into the SMAZ analysis should be documented and inspected in order to determine their overall potential impact on instrument reliability. While not documented in the setpoint methodology report, it was determined that several assumptions form the basis of the SMAZ equation as presented in the BWROG report. These assumptions on SMAZ include:

Assumption #1 — The instrument drift is random.

Assumption #2 — No correlations exists from one instrument reading to another for the terms in the SMAZ equation.

Assumption #3 — The uncertainty variance for parameters in the SMAZ equation are constant.

Assumption #4 — Analysis data represents a single point.

Questions related to these three assumptions were raised. These questions and their responses are discussed below.

Assumption #1 — The instrument drift is random.

One fundamental underlying assumption of the BWROG data analysis is that the drift for any particular component is random. If component drift is indeed random and the positive drift difference is added to the negative drift difference, then the net drift value should be approximately zero. This net drift value is defined in the GE data analysis as the mean OISD. Statistics can determine if zero is contained within the confidence interval for the OISD data points. If zero is not contained within the confidence interval for the OISD data points, then the assumption of random drift may be incorrect, which impacts the usage and evaluation of the SMAZ calculations.

In order to test the OISD data to see if zero is within the calculated data confidence interval, the confidence interval must be determined. Most standard statistical texts provide an approach to estimate the confidence interval for a set of data based upon the Student-t distribution. This approach assumes that the variance of the population is unknown. For a confidence level of 95%, the lower and upper points of the confidence interval are:

$$Lower\ Point = \bar{x} - t_{(0.025,\, n-1)} \frac{s}{\sqrt{n}}$$

$$Upper\ Point = \bar{x} + t_{(0.025,\, n-1)} \frac{s}{\sqrt{n}}$$

where $\bar{x}$ = the sample mean

$t_{(0.025,\ n-1)}$ = the Student-t distribution for confidence coefficient 0.025 and n-1 degrees of freedom

s	=	the sample standard deviation
n	=	the number of data points

The INEL performed this statistical test on two BWROG example data handouts. The results show that *most* of the confidence intervals for the calibration intervals *did not* contain zero as a point in the interval. The results of the confidence interval calculation are shown in Tables 1 and 2. Figure 1 shows a plot of the confidence intervals for component CR2820 and clearly shows the OISD confidence intervals increasing in height over time and do not encompass zero. The BWROG data analysis should provide this type of figure as part of the data analysis to assist reviewers in visualizing data trends.

Table 1. Confidence interval results for component "CR2820" data example.

Interval (Month)	OISD mean	SMAZ	Observed Sqrt(SMAZ)	# Points	Lower interval	Upper interval	Is zero within confidence interval?
1	-0.002443	5.300213	2.613571	103	-0.4532	0.4483	Y
2	0.278335	7.591979	3.127989	107	-0.2478	0.8045	Y
3	0.300111	6.749136	2.949251	97	-0.2211	0.8214	Y
4	0.532761	9.735689	3.542183	97	-0.0882	1.1538	Y
5	0.319724	10.362620	3.654454	90	-0.3530	0.9924	Y
6	0.697357	12.255027	3.974155	96	0.0007	1.3940	
7	0.473085	11.249112	3.807560	97	-0.1976	1.1438	Y
8	0.354856	12.350503	3.989606	87	-0.3925	1.1022	Y
9	0.639808	10.662083	3.706882	83	-0.0616	1.3412	Y
10	1.016819	13.755208	4.210380	83	0.2355	1.7981	
11	0.768690	12.562037	4.023627	86	0.0247	1.5127	
12	1.489094	16.213954	4.571220	84	0.6747	2.3035	
13	1.682846	17.688255	4.774525	84	0.8438	2.5219	
14	1.539288	19.743296	5.044261	89	0.6588	2.4198	
15	1.664946	21.882801	5.310546	78	0.6759	2.6540	
16	1.892487	26.293501	5.821192	77	0.8070	2.9779	
17	1.955270	26.030769	5.792035	88	0.9539	2.9566	
18	1.972923	29.118619	6.125945	87	0.8993	3.0465	
19	2.026104	28.320608	6.041419	86	0.9679	3.0843	
20	2.133833	26.763314	5.872968	85	1.1142	3.1534	
21	1.886030	27.076270	5.907206	81	0.8102	2.9619	
22	1.600497	26.586403	5.853525	77	0.4841	2.7169	
23	2.490704	28.263871	6.035365	74	1.3986	3.5828	
24	2.259581	27.909361	5.997395	76	1.1645	3.3546	
25	2.902198	29.587863	6.175107	69	1.7929	4.0115	
26	2.912451	28.563155	6.067234	67	1.8152	4.0097	
27	2.787260	28.527139	6.063408	58	1.5848	3.9897	
28	2.910428	27.247665	5.925873	65	1.8326	3.9883	
29	2.781703	29.941610	6.211911	57	1.5268	4.0366	
30	3.474312	34.840044	6.700806	58	2.2150	4.7337	
31	3.440950	32.736336	6.495352	62	2.2756	4.6063	
32	3.770419	35.528233	6.766662	53	2.4935	5.0473	
33	3.593400	31.551930	6.376768	54	2.4108	4.7760	
34	4.244644	32.357146	6.457625	52	3.1868	5.3025	
35	4.014630	34.311406	6.649775	55	2.8574	5.1719	
36	3.913847	31.831203	6.404927	49	2.7431	5.0846	
37	4.545182	39.702435	7.153132	56	3.3722	5.7181	
38	4.857705	41.114192	7.279199	52	3.6886	6.0268	
39	4.407589	32.647867	6.486570	52	3.3919	5.4233	
40	4.587320	38.678549	7.060294	47	3.3509	5.8237	
41	4.083345	34.440883	6.662310	49	2.8689	5.2978	
42	4.000629	34.442170	6.662434	48	2.7502	5.2511	
43	4.763236	40.584027	7.232114	45	3.4893	6.0372	
44	4.177852	35.059195	6.721847	40	2.8345	5.5212	
45	4.817301	35.912318	6.803140	45	3.7438	5.8908	
46	4.890713	37.265359	6.930113	37	3.6726	6.1088	
47	4.868039	32.547072	6.476549	37	3.8762	5.8599	
48	4.801619	30.891601	6.309688	34	3.8263	5.7769	

Table 2. Confidence interval results for component "184C5988" data example.

Interval (Month)	OISD mean	SMAZ	Observed Sqrt(SMAZ)	# Points	Lower interval	Upper interval	Is zero within confidence interval?
1	-0.003973	0.009536	0.097652	409	-0.0133	0.0054	Y
2	0.006719	0.010211	0.101049	400	-0.0030	0.0165	Y
3	-0.008210	0.009293	0.096400	373	-0.0178	0.0014	Y
4	-0.003586	0.012125	0.110114	366	-0.0147	0.0076	Y
5	-0.008609	0.012711	0.112743	363	-0.0200	0.0028	Y
6	-0.005419	0.013655	0.116855	346	-0.0176	0.0068	Y
7	-0.020083	0.018402	0.135654	361	-0.0338	-0.0064	
8	-0.018787	0.016960	0.130231	338	-0.0324	-0.0052	
9	-0.022364	0.018278	0.135196	313	-0.0370	-0.0077	
10	-0.022266	0.020399	0.142825	320	-0.0376	-0.0069	
11	-0.021537	0.019755	0.140552	296	-0.0372	-0.0058	
12	-0.029117	0.022259	0.149195	293	-0.0458	-0.0125	
13	-0.028692	0.026964	0.164207	281	-0.0475	-0.0099	
14	-0.029106	0.023845	0.154418	277	-0.0469	-0.0114	
15	-0.047390	0.030366	0.174258	273	-0.0672	-0.0276	
16	-0.038725	0.025277	0.158987	255	-0.0576	-0.0199	
17	-0.029426	0.021710	0.147343	257	-0.0470	-0.0119	
18	-0.038389	0.021762	0.147519	253	-0.0559	-0.0209	
19	-0.029341	0.023666	0.153838	239	-0.0484	-0.0103	
20	-0.026596	0.021264	0.145822	235	-0.0449	-0.0083	
21	-0.013432	0.020322	0.142555	228	-0.0318	0.0049	Y
22	-0.014920	0.021500	0.146629	235	-0.0335	0.0037	Y
23	-0.023181	0.022569	0.150230	213	-0.0431	-0.0033	
24	-0.017902	0.021285	0.145894	199	-0.0380	0.0022	Y
25	-0.022321	0.021341	0.146086	182	-0.0433	-0.0013	
26	-0.028143	0.022445	0.149817	171	-0.0503	-0.0060	
27	-0.013139	0.019843	0.140865	176	-0.0339	0.0076	Y
28	-0.019068	0.025655	0.160172	177	-0.0426	0.0044	Y
29	-0.029986	0.027180	0.164864	173	-0.0542	-0.0057	
30	-0.037657	0.026284	0.162123	159	-0.0623	-0.0130	
31	-0.038496	0.025052	0.158278	138	-0.0643	-0.0127	
32	-0.036654	0.029879	0.172855	133	-0.0656	-0.0077	
33	-0.049457	0.033661	0.183469	115	-0.0821	-0.0168	
34	-0.060795	0.034836	0.186644	110	-0.0942	-0.0274	
35	-0.069240	0.038744	0.196835	102	-0.1055	-0.0330	
36	-0.080620	0.035311	0.187912	119	-0.1114	-0.0498	
37	-0.101087	0.039253	0.198124	92	-0.1365	-0.0657	
38	-0.104430	0.043230	0.207918	79	-0.1448	-0.0640	
39	-0.123397	0.042619	0.206444	78	-0.1608	-0.0860	
40	-0.136458	0.042709	0.206662	72	-0.1731	-0.0999	
41	-0.150615	0.046432	0.215481	61	-0.1902	-0.1110	
42	-0.161557	0.050505	0.224733	53	-0.2048	-0.1183	
43	-0.155637	0.053812	0.231974	51	-0.2042	-0.1071	
44	-0.168155	0.049420	0.222306	42	-0.2135	-0.1228	
45	-0.155303	0.049539	0.222574	33	-0.2117	-0.0989	
46	-0.137019	0.035968	0.189652	26	-0.1895	-0.0845	
47	-0.110119	0.023808	0.154298	21	-0.1585	-0.0617	
48	-0.073810	0.010364	0.101804	21	-0.1052	-0.0424	

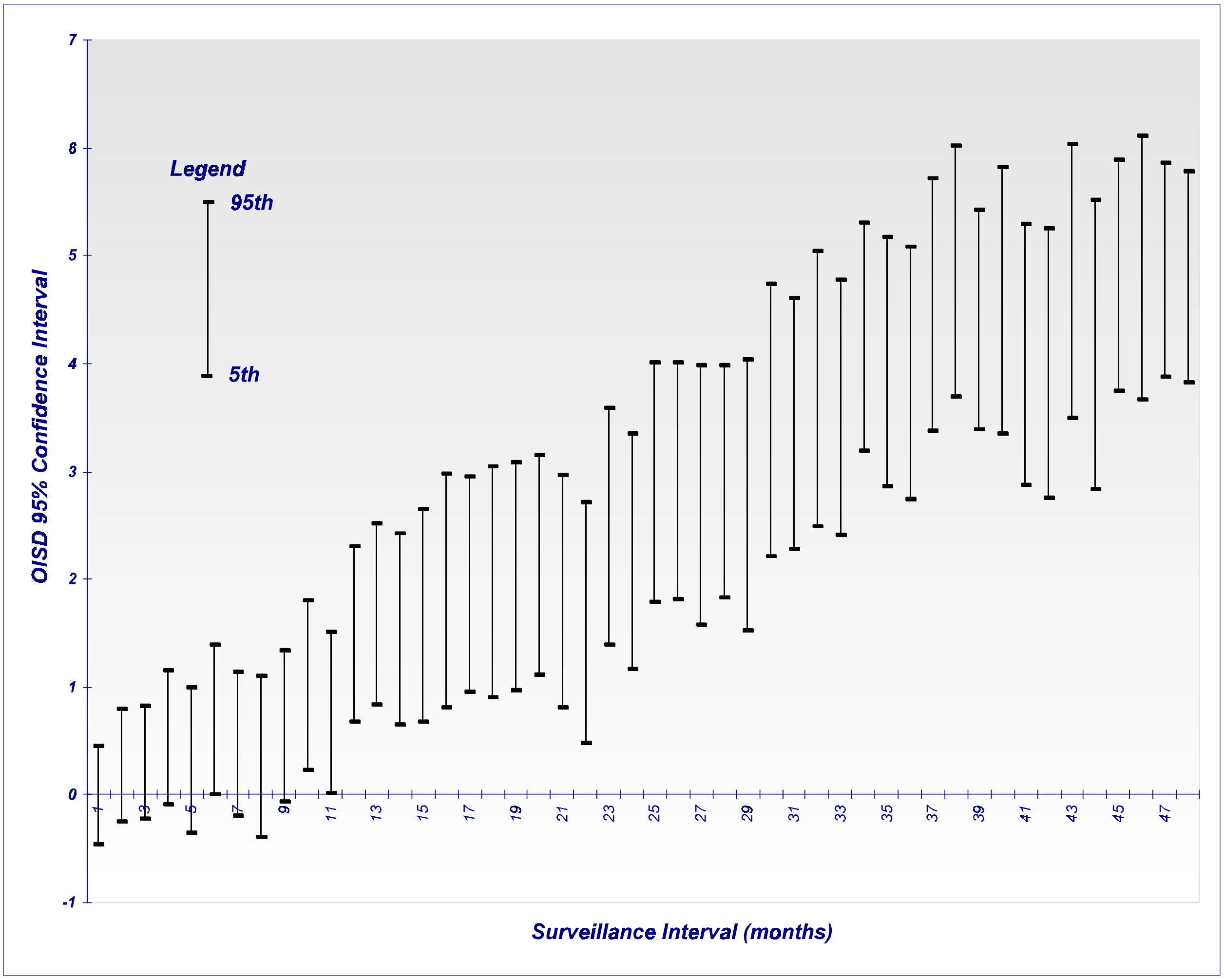


Figure 1. OISD 95% confidence intervals plotted for component CR2820.

A fundamental assumption for the BWROG data analysis is drift is random. If we assume the drift is random, the uncertainty is modeled as a random walk process (it is also known as a Wiener process or Brownian motion). To estimate the variance of the drift term, it turns out that (e.g., see Stark and Woods, *Probability, Random Process, and Estimation Theory for Engineers*, page 274):[19]

$$Var(Drift) = \frac{t}{T} s^2$$

where t = the length of the i'th interval

T = the length of the interval corresponding to the sample variance s^2

s^2 = the sample variance for an interval of length T.

A sample function of the Weiner process is shown below. As can be seen in the figure, the variation in the process (where the process we are interested in is the instrumentation drift) increases over time. It is this increasing variation over time that limits our ability to predict and control drift over long calibration intervals (e.g., 45 months).

Figure 2. A sample function of the Wiener process (Reference 19).

Three fundamental assumptions for the random walk process described previously are

(1) The *mean* of the process is equal to zero

(2) The random walk is truly *random* (i.e., has no bias to one side or the other)

(3) The sample variance is a *constant* for the interval of length T.

From the test using the confidence intervals discussed above, it was shown that the mean of the drift process for two data sets is not zero. Question 7, RAI #2, discussed the underlying assumptions on drift used for the SMAZ calculation. The BWROG response to the question stated "...the methodology is intended to provide a conservative basis for calculating Allowable $(SMAZ)^{1/2}$. No bias is explicitly provided for in this equation. If bias occurs, it is a threat to violation of the Allowable $(SMAZ)^{1/2}$ by the data; it is not a reason to conclude that the equation to calculate Allowable $(SMAZ)^{1/2}$ is unacceptable." INEL takes exception to this response for two reasons.

First, the claim of "conservative" calculation by the BWROG for the SMAZ results is suspect. The INEL pointed out several items which may result in the original SMAZ calculations being *nonconservative* with respect to corrected SMAZ calculations (i.e., as presented by INEL). These items include: (1) ignoring potential correlations underestimates the Allowable SMAZ calculation, (2) ignoring potential changes in the month-to-month variability underestimates the overall uncertainty on the SMAZ calculation, and (3) the overall uncertainty on the confirmation ratio results are not calculated nor used during application of the methodology.

Secondly, even if the original SMAZ calculation were "conservative," obtaining a "conservative" answer using an invalid equation does not justify the results. Granted, the answer would be "conservative" given the assumptions used to generate the answer. But, if the assumptions are not valid (or, at least, unquestioned) to begin with, the "conservative" answer has no bearing on the issue being evaluated.

Assumption #2 — No correlations exists from one instrument reading to another for the terms in the SMAZ equation.

Question 5 from RAI #2 discussed the potential for correlation entering the SMAZ calculation. Restating the question, it was pointed out that the calculation for the allowable SMAZ is:

$$\sqrt{SMAZ}_{allowable} = \sqrt{\sigma^2_{accuracy_1} + \sigma^2_{accuracy_2} + \sigma^2_{cal.\ error_1} + \sigma^2_{cal.\ error_2} + \sigma^2_{drift}}$$

where the sigmas represent one standard deviation of the accuracy term, the calibration error term, and the drift term, respectively (assuming that the temperature effect term is zero).

The above SMAZ equation assumes that *each* of the terms in the equation are independent. If any dependency is found from point-to-point for instrumentation readings or calibrations, the above SMAZ equation is not valid. Instead, the correlation between the dependent parameters would need inclusion in the equation. Thus, the new equation would be:

$$\sqrt{SMAZ}_{allow.} = \sqrt{\sigma^2_{acc._1} + \sigma^2_{acc._2} - (2\,\rho_a \sigma_{acc._1} \sigma_{acc._2}) + \sigma^2_{cal.\ err._1} + \sigma^2_{cal.\ err._2} - (2\rho_c \sigma_{cal.\ err._1} \sigma_{cal.\ err._2}) + \sigma^2_{drift}}$$

where the ρ terms are the usual correlation coefficients.

The new SMAZ equation has two new terms which, in general, subtract from the original terms in the equation. Consequently, any correlation could effectively lower the allowable SMAZ value (and would increase the confirmation ratio). Question 5 asked for a demonstration that the point-to-point instrumentation readings are completely independent (as implied in the original SMAZ calculation).

The response to Question 5, RAI #2, contested the correlation issue by illustrating a case where “At time 1 each instrument makes its random draw, but at time 2 it makes the same draw.” The BWROG response did not address the point behind the issue of potential point-to-point correlations. If an instrument gives the *same* reading time after time, the instrument could be *non-functional* since process equipment should demonstrate variability over time. Conversely, correlated readings will still have “randomness” as part of the reading. Since the equipment, procedures, personnel, etc., used to perform the inservice instrument readings are taken from the same pool each time the instrument is tested, there are inherent correlations between the observed inservice differences (OISD) data points. Consequently, these potential correlations must be accounted for in the SMAZ calculations. Thus, Question 5, RAI #2, has not been answered satisfactorily by the BWROG response.

It should be pointed out that the SMAZ methodology attempts to predict outcomes of extended surveillance intervals (e.g., 45 month intervals) using much shorter interval data (e.g., 18 month data). As with any statistical method, extrapolating a prediction into the future exaggerates any uncertainty present in the model and the data used in the model. This exaggeration of the overall uncertainty must be factored into the decision-making process. Also, it was pointed out that the interval data is actually synthesized data and had inherent correlations due to the overlapping of time intervals used to construct the “data.”

Assumption #3 — The uncertainty variance for parameters in the SMAZ equation are constant

Both of the SMAZ calculations with and without the correlation terms assume that the variance for each parameter is constant over time for the calibrations made from one calibration to the next. If either the variance (e.g., the standard deviation squared) on the accuracy term, the calibration error term, or the drift term varies as a function of time, then the SMAZ equation is not correct. Question 6 asked for a demonstration that the actual recorded variances (as given by the OISD data) do not vary as a function of time.

The response to Question 6, RAI #2, stated "...[the accuracy and calibration terms] occur twice in an OISD, and is irrespective of the time interval over which the OISD applies." This response does not answer Question 6 since usage of the SMAZ equation assumes that the variance in calibration data over time is constant. The accuracy and calibration terms are "irrespective of the time interval" because the underlying formulation of the original SMAZ equation assumes that the variances are constant over time. The response to Question 6 further states "...variance in accuracy and calibration from month-to-month is constant since they appear twice in the SMAZ formulation," without providing a link between the calibration variance and the SMAZ formulation. The calibration variance is not constant because certain terms appear in a SMAZ equation. Calibration variance is a physical property of the calibration itself and does not care about a SMAZ equation. Conversely, if the calibration variance is not constant, the SMAZ equation presented in the BWROG report is incorrect. The BWROG must demonstrate that the calibration variance is constant over the period of time applicable for the data analysis described in the BWROG report.

Assumption #4 — Analysis data represents a single point.

The data, as presented in the BWROG report, represents a single data value for a particular instrument reading (e.g., the as-found or as-left instrument values). While it is clear that the SMAZ analysis assumes that this value is a single point, it may be possible that the data point was really something other than a single reading. For example, a reading could actually have been an average of a 5 or 9-point calibration or data check. Alternatively, the reading could have been a single value from a multipoint check. Or, the reading could have been a median value from multiple, single point readings. The description of the data collection and analysis does not clarify what the data reading are as presented in the analysis. Guidance must be provided addressing the various types of data and calibration information that could be collected as part of a calibration interval extension and their respective impact on the SMAZ methodology.

4. Overall uncertainty in the analysis results are not presented nor discussed

The calculation of the calibration confirmation ratio involves a division of the observed SMAZ by the allowable SMAZ, and is given by the equation

$$Confirmation\ \ Ratio\ =\ \frac{SMAZ_{observed}}{SMAZ_{allowable}}$$

In the analysis handouts provided to the INEL, this confirmation ratio calculation was performed with point estimates only. Both the observed SMAZ and the allowable SMAZ are random variables. That is, they both have some uncertainty. Consequently, to correctly evaluate the confirmation ratio, one should evaluate the uncertainty about the confirmation ratio. As an example of how to evaluate the uncertainty, a ratio calculation was postulated. Suppose that:

Observed SMAZ is normally distributed with mean = 5.63, standard deviation = 0.503
Allowable SMAZ is normally distributed with mean = 10.0, standard deviation = 1.022

While it is assumed that the SMAZs are normally distributed, this assumption would need to be checked. (The SMAZ uncertainty should be approximately normally distributed.) Using the example above, the GE analysis would simply take the mean values (i.e., point estimates) and divide them, giving the confirmation ratio. Thus, the confirmation ratio is 5.63/10.0 = 0.563. When the uncertainty is evaluated using Monte Carlo sampling, it is found that the confirmation ratio results are: Mean = 0.57, 50th = 0.56, 95th = 0.71. Thus, if the analysis methodology were correct (which is suspect given the numerous problems identified with the methodology), the analysis for this particular component would indicate an acceptable confirmation ratio. But, we would still need to have specified the confidence intervals on the probability percentiles. Additionally, criteria should be specified addressing the case where some of the intervals meet the acceptance criteria while other intervals *do not* meet the acceptance criteria for the same set of data.

The treatment of uncertainty on the final calculation should be incorporated into the calibration analysis (especially in light of the fact that the uncertainty was evaluated at every step in the process up to the final calculation). The setpoint methodology report (Reference 2) used a 95% probability evaluation for setpoint determination. The calibration interval report (Reference 1) discusses a 50%/95% value which implies 50% confidence interval on a 95% probability. The analysis presented above represents a 95% confidence interval. The BWROG should decide on and present discussion of an acceptance criteria to be used for the results of the SMAZ analysis.

3.4 Plant Safety, Operations, and Cost Benefit Evaluation

The BWROG maintains that the proposed extension of calibration intervals provides an overall improvement to plant safety and operations, and that the proposed changes will result in cost beneficial licensing actions. The topical report identifies the following as improvements:

1. Reduced potential for false safety system actuations (fewer events requiring LERs),
2. Reduced radiation exposure to plant personnel (ALARA),
3. Reduced test cycles on equipment,
4. Reduced diversion of plant personnel and resources for unnecessary testing,
5. Reduced challenges due to lifting leads,
6. Reduced opportunity for error,
7. Increased safety system availability,
8. Fewer LCOs due to testing, and
9. Lower O&M costs.

The INEL reviewers performed an evaluation of each of the proposed improvements to plant safety and operations and O&M cost benefits resulting from the proposed calibration interval extension. Each of the areas of potential improvements identified by the BWROG are shown below, followed by some possible examples of degradation (i.e., drawbacks) to plant safety, operation, and O&M costs resulting from the proposed calibration interval extension, which were not discussed in the report.

1. Reduced potential for false safety system actuations (fewer events requiring LERs)

Calibration of safety system instrumentation can raise the potential for false safety system actuations, resulting in an increase in LERs. However, safety system actuations caused by instrument calibrations are normally the result of human error, poor administrative controls, or inadequate procedures. False safety system actuations can be greatly minimized through improvements in administrative controls and calibration procedures. Consequences of these false safety system actuations are greatly reduced during plant shutdown. Therefore, process sensor instrumentation is calibrated during plant shutdown conditions as part of a Channel Calibration surveillance. When the calibration of process sensor instrumentation is not performed during a period of plant shutdown, there may be an increased potential for safety system actuations during and after plant startup caused by instrument failures which are identifiable only by performance of a Channel Calibration during shutdown conditions. Periods of plant shutdown cause some credible failures of process sensor instrumentation, such as, air in fluid sensing lines, cold junctions in thermocouples, or loss of level system reference legs. Performance of Channel Calibrations before plant startup help alleviate these types of failures, optimizes process sensors outputs, and assures instrument channel health after a period of shutdown. The topical report does not discuss the increased potential for false safety system actuations caused by instrument failures which could be identified during Channel Calibrations. Furthermore, the most commonly used process instruments included in the BWROG safety systems (as referenced in the topical report) are contact output devices (temperature switches, pressure switches, etc.), which are not monitored for calibration drift by any other method except Channel Calibration surveillance. Therefore, the reduction in false safety system actuations due to the proposed calibration interval extension cannot be verified.

2. Reduced radiation exposure to plant personnel (ALARA)

Calibration of process sensor instrumentation is normally performed during plant shutdown. In many cases, plant personnel are required to enter radiation controlled areas to perform these calibrations. Therefore, an extension of calibration intervals from 18 to 36 months would reduce the radiation exposure to personnel performing calibrations. However, an unplanned shutdown caused by an instrument failure (which may have been eliminated by the performance of a Channel Calibration) may result in a greater exposure of plant personnel due to the plant configuration and lack of job planning. The topical report does not address the potential for increased personnel radiation exposure during an unplanned shutdown, which could offset the discussed reduction. Therefore, the reduction in plant personnel radiation exposure cannot be verified.

3. Reduced test cycles on equipment

Channel calibrations are normally performed by perturbing the process sensor with a simulated input while monitoring sensor output with measuring and test equipment, and at the same time monitoring the associated end-devices for proper actuation and indication. If the process instrument is within its calibration tolerance, there are no adjustments (e.g. bias, span, zero, setpoint) necessary. If the instrument requires adjustment to optimize its output within tolerance values, it is likely the calibration test cycle was necessary. Therefore, the impact of this argument for cost-benefit impact is minimal.

4. Reduced diversion of plant personnel and resources for unnecessary testing

As previously discussed, without performing a calibration during shutdown, it is difficult to assess the need for the calibration until the plant is in operation, resulting in a possible failure on demand or an unplanned shutdown to correct a failure that may have been identifiable during a Channel Calibration at shutdown. During a plant shutdown, many activities are underway, including modifications, maintenance, and design changes. In many cases, a Channel Calibration provides needed assurance that safety system components and circuitry are correctly restored before plant startup. The topical report did not address this concept, nor evaluate the consequences of these potential failures, therefore, a cost benefit resulting from a reduction in plant personnel and resources for performance of Channel Calibrations is not verified.

5. Reduced challenges due to lifting leads
6. Reduced opportunity for error

Lifting leads for the purpose of calibration and other human errors during calibration activities increases the potential for safety system challenges. But, current I&C system design standards require safety system instrumentation to be designed with testing features which minimize the need for lifting leads. IEEE Std 338-1987 Section 5.0, subpart 12, states "Where practical, test devices, such as test blocks, should be incorporated into the design to eliminate the application and removal of wires in order to perform periodic surveillance testing. These devices shall not interfere with the operability or safety function of the component or system under test." Most instrument calibrations are performed without the need to lift signal leads at the process instrument. Also, through years of plant operations, well written and controlled administrative procedures, calibration procedures, and maintenance programs have been established which greatly minimize the potentials for error. This is represented by the low operator testing error probabilities used in most PRA studies.

Channel and Logic System Functional test activities inside the safety system instrument racks present the most significant safety system challenges, because these activities are conducted during reactor operation and leads are more often lifted during the performance of these testing activities. Additionally, the maintenance bypass function of reactor protection and engineered safety features actuation systems provided for on-line testing, and the reduced actuation logic coincidence resulting from the test bypass features, result in challenges to safety systems. Channel Calibrations during plant shutdown do not depend on many of the test bypass features, therefore, the increase in safety system challenges is greatly reduced for Channel Calibration. Furthermore, Channel Calibrations performed during refueling shutdown in many cases identify problems in instrument systems such as lifted leads and configuration errors caused by outage activities such as plant modifications, design changes, and maintenance activities. An increase in Channel Calibration test intervals may reduce challenges to safety systems due to a reduced number of lifted leads and other potential errors, however, the added verification of instrument channel operability following outage activity is also lost. Information provided in the topical report did not address the additional operability assurance provided by Channel Calibrations. Therefore, the cost benefit of not performing a Channel Calibration following periods of plant shutdown is not verified.

7. *Increased safety system availability*
8. *Fewer LCOs due to testing*

The proposed calibration interval extension reduces the number of times process instruments are out of service for calibration. However, since these calibrations are normally performed during refueling outages, many of the safety systems affected by these instruments are not required or are under reduced operability requirements (less restrictive LCOs). In most cases, when instrumentation is out of service (inoperable) for a period of time (e.g., source range instrumentation), LCOs require a calibration to be performed before operability is reestablished. IEEE 338-1987 Section 6.5.2 states: "Test intervals may be changed to agree with plant operational modes provided it can be shown that such changes do not adversely affect desired performance of the equipment being tested. Tests need not be performed on systems or equipment when they are not required to be operable or are tripped. If tests are not conducted on such systems, they shall be performed prior to returning the system to operation." The INEL reviewers considered the increase in safety system availability to be insignificant in comparison to the loss of safety system operability assurance provided by Channel Calibrations. It was also noted that a significant number of I&C safety system instruments are inoperable during shutdown periods, which raises the question of whether or not the instruments should be calibrated prior to returning to service based upon IEEE Std 338 requirements.

9. *Lower O&M costs*

The proposed calibration interval extension would reduce the number of required refueling outage calibrations by up to 50% (each required instrument calibrated every other 18 month refueling outage). This reduction in the number of calibrations performed each refueling outage results in a 50% reduction in O&M costs associated with this task. However, the increased risk introduced by the proposed increase in calibration intervals, and the decreased assurance of instrument system health and performance upon demand, may increase the number of unplanned shutdowns. Any increase in the number of unplanned shutdowns could outweigh the O&M cost savings associated with calibrating these instruments during each refueling outage. In general, additional analysis is required before lower O&M costs due to calibration interval extension can be evaluated and validated.

4.0 Conclusions and Suggestions

To summarize the overall findings of the INEL review of the BWROG Calibration Interval Extension report, NEDC-32160P, the reviewers found that the report and responses to questions on the report were inadequate in several areas. These areas covered a spectrum of issues, including: applicability to NRC Generic Letter 91-04, PRA considerations, statistical data analysis techniques, and general safety/benefit considerations. Specific deficiencies were addressed for each area. While details for each deficiency are presented in the body of this report, they are summarized and are listed below according to relevant areas.

- The BWROG methodology to project of process drift for extended periods of time (e.g., 45 months) is questionable due to the numerous concerns that were raised about the BWROG calibration extension methodology. (Section 3.3, Item 3)

- The GE setpoint methodology does not adequately confirm that instrument drift will stay within acceptable limits for extended periods (e.g., greater than 24-month calibration intervals). (Section 3.3)

- The BWROG states that, “surveillance records show that projected drift values for 45 months have not been exceeded except on rare occasions”, however, no calibration data or other supporting documentation was provided to support the statement. (Section 3.1.1)

- Projected instrument drift values resulting from the BWROG methodology were compared with vendor allowable drift values to determine the acceptability of the projected values. The vendor allowable drift values for a 45 month time period were not included in the topical report for evaluation. (Section 3.1.1)

- Projected instrument drift values resulting from the BWROG methodology were compared to vendor allowable drift values instead of allowable values established by an acceptable setpoint analyses. (Section 3.1.1)

- For new instrumentation installed in safety systems, BWROG has not provided a documented methodology for establishing calibration intervals. This concern applies to any application of the calibration extension methodology for instruments without a recorded as-found and as-left calibration history. (Section 3.1.1)

- Overall uncertainty (and correspondingly, confidence) on the calibration extension methodology are not presented. (Section 3.3, Item 4)

- Acceptance criteria for drift and unreliability are not mentioned as part of the analysis. (Sections 3.22, 3.23, and 3.1.3)

- Data analysis for twenty two instruments was provided as part of the report, but nine of the instruments that were analyzed are unrelated to the issue of calibration extension, and the remaining instruments are contact output devices which cannot be monitored by alternative methods. Also, for the reliability analyses that were performed, details of the calculations must be provided. (Section 3.1.5)

- Extensions of calibration intervals could result in operational difficulties besides those caused by random instrument drift. Consequently, focusing solely on drift issues results in too narrow of a view of risk and reliability impacts from extending calibration intervals. (Section 3.4)

- It was determined that only Channel Calibrations, Channel Checks and other enhanced monitoring methods based on redundant channel comparisons are useful in determining process sensor availability and performance. For the process sensor instruments included in the study, monitoring methods such as operator observation and channel checks are not applicable. Therefore, the process instruments would be required to maintain calibration within allowable values for up to 45 months, with no other means of failure detection. (Section 3.1.5)

- Potential increases in the probability of common-cause failures should be addressed in any reliability or risk assessment calculations. Also, time-dependent concerns (of which, drift is one aspect) should be factored into the analysis. (Section 3.2.1, Items 2 and 3)

- The overall impacts to (1) the plant core damage frequency and (2) operational risk are not qualified/quantified in the study. (Sections 3.2.2 and 3.2.3)

- Although the BWROG report provides anticipated benefits from increasing calibration intervals, many potential drawbacks were not addressed. Consequently, potential drawbacks from calibration interval extension were identified by the reviewers. (Section 3.4)

- The topic of plant specific analysis versus generic analysis is of concern. Specifically, the BWROG study states that plant specific analysis is not required. It was not demonstrated that only generic analysis is adequate. (Section 3.3, Item 1)

- Several concerns were raised for the BWROG drift data analysis. First, the data analysis program incorrectly categorizes the operational drift data. Second, many of the assumptions underlying the analysis methodology were not presented. Questions pertaining to these assumptions must be answered before the methodology is used as part of the justification for calibration interval extension. Third, the overall uncertainty on the data analysis is not quantified and presented. Like any numerical analysis technique, the results are only as good as the underlying model and data that goes into the model. (Section 3.3, Items 2, 3, and 4)

The BWROG report is inadequate to justify calibrations interval extensions. To have a potentially acceptable analysis, the INEL reviewers recommend (at a minimum) the following items be adequately analyzed and discussed:

- Before any analysis (e.g., statistical, risk assessment) is performed, a list of the specific instruments affected by the calibration interval should be generated and documented. Performing and documenting analyses for instruments that have limited importance to the issue of calibration extensions only obscures the relevant issues.

- After generating a list of affected instruments, it should be used for three purposes. First, concerns relating to instrument channel inoperability and the potential decreased channel redundancy due to calibrations being performed every other refueling outage must be addressed. Second, operational data (e.g., drift data, exposure times, demands, failures) should be collected for these instruments so that statistical analyses will use relevant data. And third, using instrument drift data, where applicable, the overall reliability impact on instruments due to calibration interval extensions must be assessed.

- When addressing instrumentation operability issues, the analysis and documentation should incorporate all potential functional failure impacts, not only drift-related impacts.

- The drift data analysis must use an accepted statistical model where all underlying assumptions are investigated for applicability to the data modeling. Also, the analysis should not arbitrarily filter data and should group all applicable data into appropriate groups.

- The reliability analysis should use accepted modeling practices. All impacts to functional failures must be included in the reliability analysis to account for the increased failure probability of components undergoing increased calibration intervals. Issues, such as common-cause failure potentials and operator error, must be included in the analysis.

- Once the reliability analysis is complete, the overall impact on both the core damage frequency and operational risk should be quantified and documented.

- Instrumentation vendor documention must be provided that supports a 45 month time period if the vendor allowable drift values are cited as supporting justification for the extended calibration intervals.

- The BWROG must provide a methodology for establishing calibration intervals for new safety system instrumentation installed in the future.

- If, after adequate analysis and documentation is presented and the calibration intervals are extended, a strong feedback loop must be put into place to ensure that drift, tolerance, and operability of affected components are not negatively impacted. The data collection and analysis should reflect the original analysis conclusions. However, due to the extended calibration intervals, obtaining an adequate amount of meaningful data would require many years of data collection. Data obtained from the extended calibration interval would not be timely nor provide effective feedback in analyzing the impact from the calibration interval extension. The BWROG must address the methodology for obtaining reasonable and timely feedback.

- The SMAZ methodology attempts to predict outcomes of extended surveillance intervals (e.g., 45 month intervals) using much shorter interval data (e.g., 18 month data). As with any statistical method, extrapolating a prediction into the future exaggerates any uncertainty present in the model and the data used in the model. This exaggeration of the overall uncertainty must be factored into the decision-making process.

Lastly, the underlying "theme" of the BWROG analysis and report is that (1) drift is the only issue of concern, (2) drift is not a problem for extended intervals, and (3) therefore extending calibration intervals to long time periods (e.g., 45 months) is acceptable. The INEL reviewers strongly oppose this line of reasoning and maintain that instrument drift is not the only item of concern. The issues raised concerning the BWROG data analysis cause the entire drift analysis to be questionable, thereby invalidating the position of "drift is not a problem." And lastly, extending calibration intervals has a varied impact on plant operations and instrumentation operability. This impact can be quantified by several measures including component/system reliability, core damage frequency, and operational risk. The BWROG report does not adequately address any one of the three measures.

5.0 References

1. GE Nuclear Energy, *Calibration Interval Extension*, NEDC-32160P, December 1992.

2. GE Nuclear Energy, *General Electric Instrument Setpoint Methodology*, NEDC-31336, October 1986.

3. U.S. NRC Generic Letter 91-04, Enclosure 2, "Guidance for Addressing the Effect of Increasing Intervals on Instrument Drift and Safety Analysis Assumptions," May 10, 1991.

4. Regulatory Guide 1.105, "Instrument Setpoints for Safety-Related Systems."

5. ISA-S67.04, "Setpoints for Nuclear Safety-Related Instrumentation Used in Nuclear Power Plants."

6. Matthew Chiramal, to Bill Zarbis, "Request #2 for Additional Information in Support of the Staff Review of Topical Report NEDC-32160P *Calibration Interval Extension,*" September 14, 1994.

7. R. A. Pinelli to Jared S. Wermeil, "Responses to the NRC questions provided in references 2 and 3 pertaining to BWROG Licensing Topical Report NEDC-32160P," BWROG-95095, November 20, 1995.

8. IEEE Std 338-1987, *IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems*, 1987.

9. Electric Power Research Institute, *Instrument Calibration and Monitoring Program*, EPRI TR-103436, December 1993.

10. L. A. England, to Jared S. Wermiel, "BWR Owners Group Calibration Interval Extension", BWROG-94004, January 12, 1994

11. H. M. Hashemian et al., *Long Term Performance and Aging Characteristics of Nuclear Plant Pressure Transmitters*, NUREG/CR-5851, March 1993.

12. Jared S. Wermiel to Donald Rockwell, *Request For Additional Information in Support of the Staff Review of the Staff Review of Topical Report NEDC-32160P "Calibration Interval Extension"*, September 7, 1993.

13. Jared S. Wermiel to T. A. Green, "Request for Additional Information in Support of the Staff Review of Topical Report NEDC-32160P *Calibration Interval Extension*," April 11, 1994.

14. W. E. Vesely et al., *Evaluation of Diesel Unavailability and Risk Effective Surveillance Test Intervals*. NUREG/CR-4810, May 1987.

15. I. S. Kim et al., *Quantitative Evaluation of Surveillance Test Intervals Including Test-Caused Risks*, NUREG/CR-5775, February 1992.

16. H. M. Stromberg et al., *Common-Cause Failure Data Collection and Analysis System Volume 1 — Common-Cause Failure Overview*, INEL-94/0064, December 1995.

17. R. S. Enzinna, S. H. Levinson, *Justification for Increasing the Engineered Safety Features Actuation System (ESFAS) On-Line Test Intervals*, BAW-10182, February 1992.

18. G. P. Simion et al., *Risk Analysis of Highly Combustible Gas Storage, Supply, and Distribution Systems in PWR Plants*, NUREG/CR-5759, June 1993.

19. H. Stark and J. W. Woods, *Probability, Random Processes, and Estimation Theory for Engineers*, Prentice-Hall, New Jersey, 1986.

Appendix A — Concerns on Data Grouping Performed by BWROG Data Analysis Program

Question 4.1, RAI #2 pointed out that the BWROG data analysis program incorrectly groups intervals. If we use the BWROG definition (as stated in their response) of a three month interval (63 days to 116 days), the BWROG data analysis program *is not* appropriately categorizing the data. To demonstrate this problem, a subset of the data, from the CR2820 data analysis handout from the October 21, 1993, meeting (i.e., the same data as discussed in the RAI #1) is presented. Looking at page 15 of the handout [observed in service differences (OISDs) for interval 003, component B2104M103], the data points 27 through 30 are:

Item	From	To	Interval	As-left	As-found	OISD
27	5/88	8/88	3	109.0	105.5	-3.5
28	7/88	10/88	3	107.0	106.0	-1.0
29	8/88	11/88	3	105.5	104.1	-1.4
30	10/88	1/89	3	106.0	102.0	-4.0

Looking at the recorded data points, it was found that the "From" and "To" dates were actually:

Item	From	Actual from date	To	Actual to date	Actual interval
27	5/88	5/4/88	8/88	8/25/88	113 days
28	7/88	7/27/88	10/88	10/3/88	67 days
29	8/88	8/25/88	11/88	11/17/88	84 days
30	10/88	10/3/88	1/89	1/14/89	103 days

If the data points are examined from the 5/4/88 to 1/14/89 date, several different individual test intervals can be found by looking at the combinations of test dates. The test dates are the days where the B2104M103 instrument was checked and a reading recorded. These dates included 05/04/88, 06/29/88, 07/27/88, 08/25/88, 10/03/88, 11/17/88, 12/15,88, and 01/14/89. Potential three month intervals can be found by determining the combinations of these dates that make up a time intervals of about 90 days. The time intervals (i.e., time from test "X" to test "Y") are:

(a) 05/04/88 to 06/29/88 = 56 days
(b) 06/29/88 to 07/27/88 = 28 days
© 07/27/88 to 08/25/88 = 29 days
(d) 08/25/88 to 10/03/88 = 39 days
(e) 10/03/88 to 11/17/88 = 45 days
(f) 11/17/88 to 12/15/88 = 28 days
(g) 12/15/88 to 01/14/89 = 30 days

If we are only interested in a 3-month interval, we can look for intervals (or groups of intervals) that are close to three months (actually between 63 and 116 days). Evaluating the interval data, we find several different possible combinations:

(a) = 56 days	(a) → (b) = 84 days **
(a) → © = 113 days **	(b) → © = 57 days
(b) → (d) = 96 days **	(b) → (e) = 141 days
© → (d) = 68 days **	© → (e) = 113 days **
(d) → (e) = 84 days **	(d) → (f) = 112 days **
(e) → (f) = 73 days **	(e) → (g) = 103 days **
(f) → (g) = 58 days	

where the intervals labeled with the "**" fall within the three month "region." Consequently, we find ***nine*** test intervals in the data from 5/4/88 to 1/14/89 that constitute a 3-month interval. But, the BWROG data analysis program determined that only ***four*** test intervals fit the 3-month interval criteria. The four intervals that were generated by the BWROG program consisted of:

Item	Actual length of interval
27	113 days (3.7 months)
28	67 days (2.2 months)
29	84 days (2.7 months)
30	103 days (3.3 months)

Comparing the BWROG program intervals with the correct intervals discussed above, it can be seen that the four program-generated intervals are correctly grouped into the three month category. But, the program did not generate nor use the three month intervals of 96, 73, 84 (2nd), 113 (2nd), and 112 days. The BWROG program missed the majority of valid intervals in this subset of data. Therefore, we conclude that the program ***is not*** correctly grouping and analyzing the surveillance data.